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Integration Of Optical Beam Loss Monitor For CLARA

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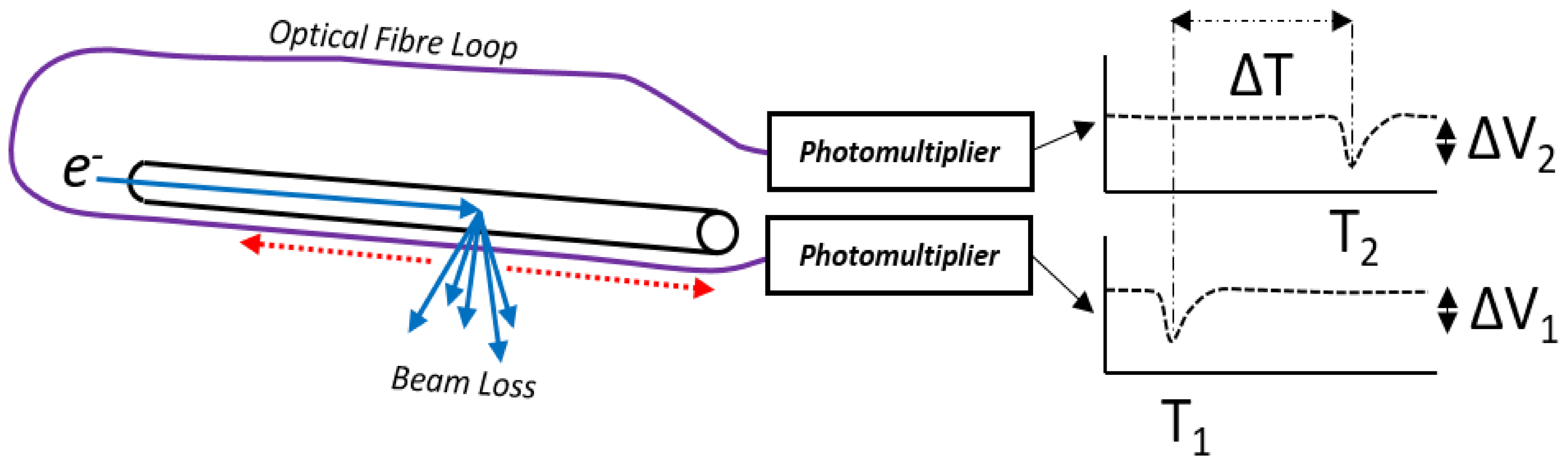
Optical Beam Loss Monitor

An oBLM system consists of a fibre placed along a beamline with photodetectors and readout hardware at the end of the fibre. The operating principle of an oBLM is based on Cherenkov radiation generated as a result of electromagnetic radiation crossing the fibre. This occurs when the particle beam hits any obstacle. The flash of Cherenkov radiation travels down a quartz fibre and is then detected by a silicon photomultiplier. By comparing the arrival time of the response from either end of the fibre it's possible to localise the position of the beam loss relative to the middle of the fibre.

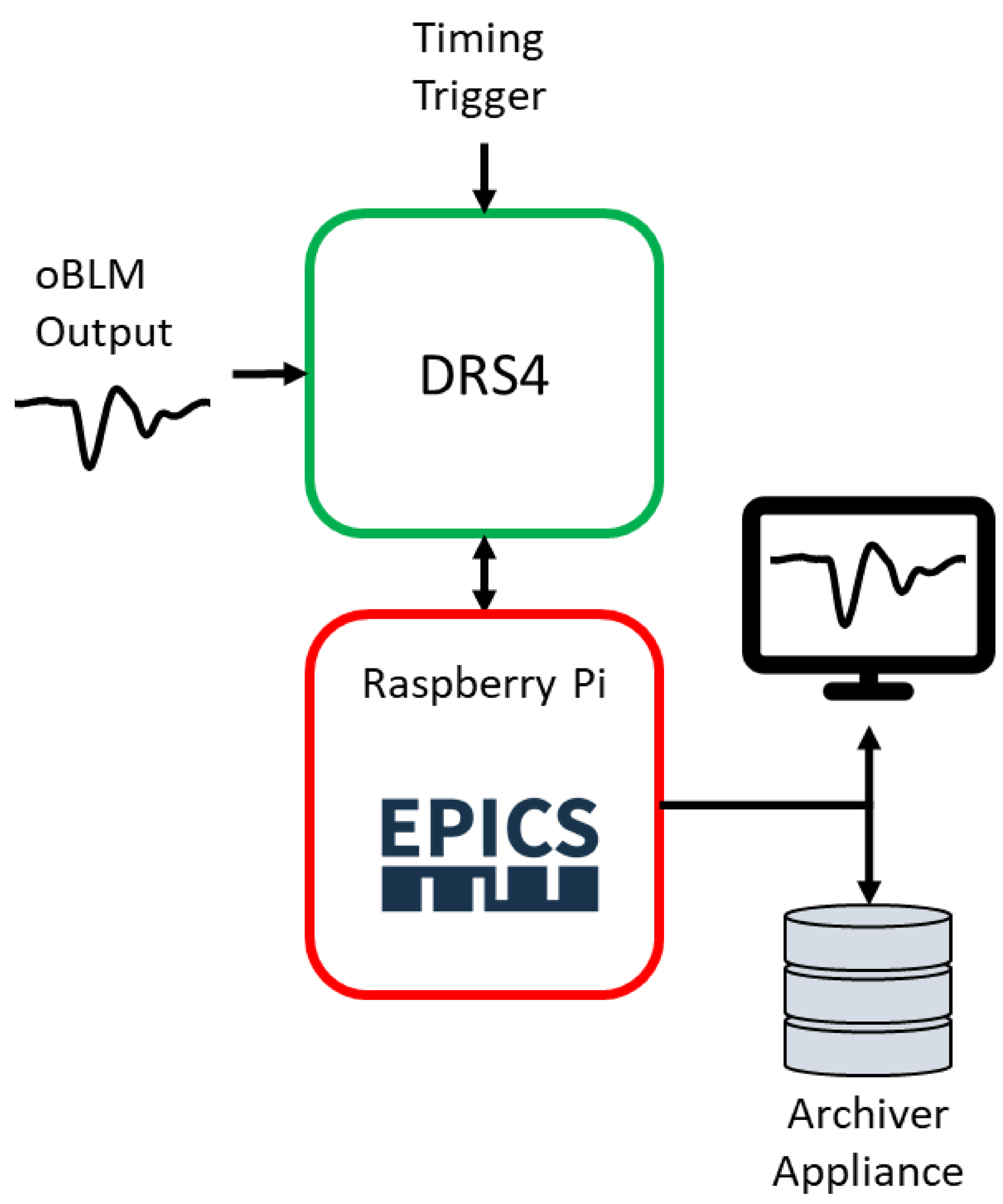


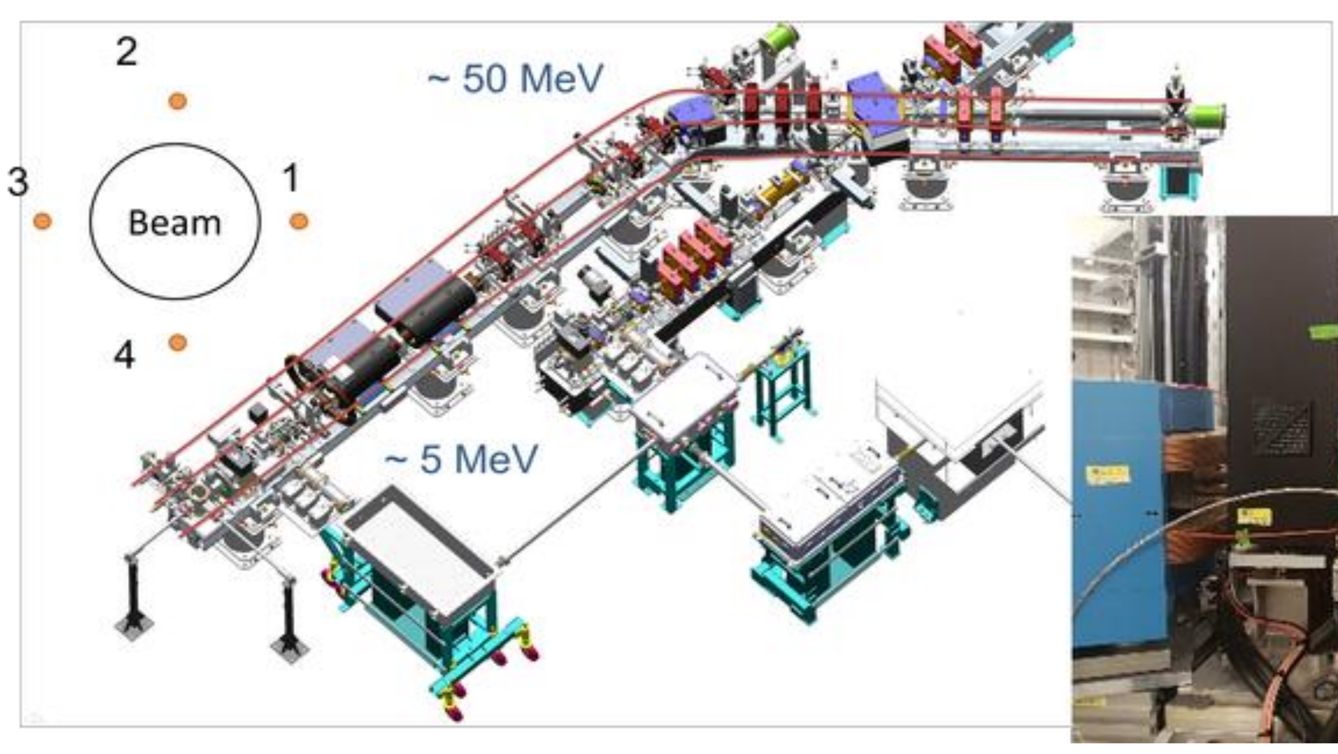
Knowing the position and intensity of beam losses is useful for optimising beam trajectory, machine and personnel protection and monitoring RF breakdown. Unlike conventional BLMs the whole length of the facility can be monitored. The use of silicon photomultipliers makes the devices insensitive to magnetic fields.

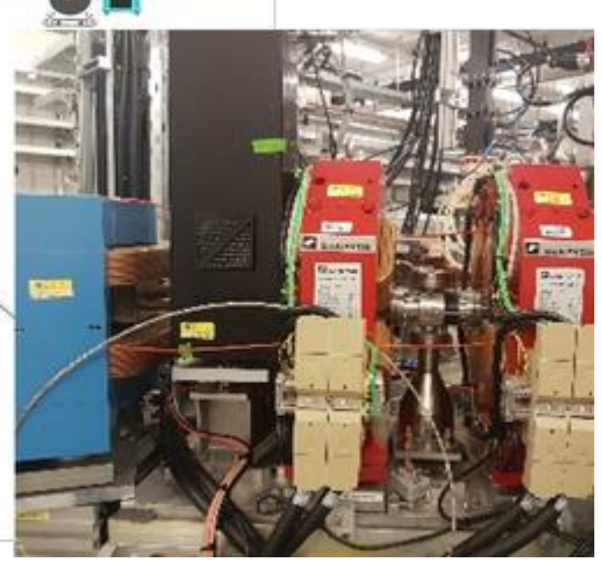
Data Acquisition System

A data acquisition system was required that would be able to reconstruct the signals from the detector and provide sufficient timing resolution to resolve beam loss events to individual components on CLARA. A DRS4 evaluation board from PSI provided a high sampling rate, >1Gsps, at a low cost, €1200. Existing lower rate sampling hardware used for other diagnostics in CLARA would have required interpolation of samples, adding complexity.

The DRS4 is a switched capacitor array that acts as an analog buffer, this is read using an ADC. The evaluation board was controlled over a USB connection with a Raspberry Pi running and EPICS IOC. Data acquired from the 4 channels of the DRS4 is made available over the channel access network and can be correlated with other diagnostics. It's presented to users and archived using the EPICS archiver appliance.

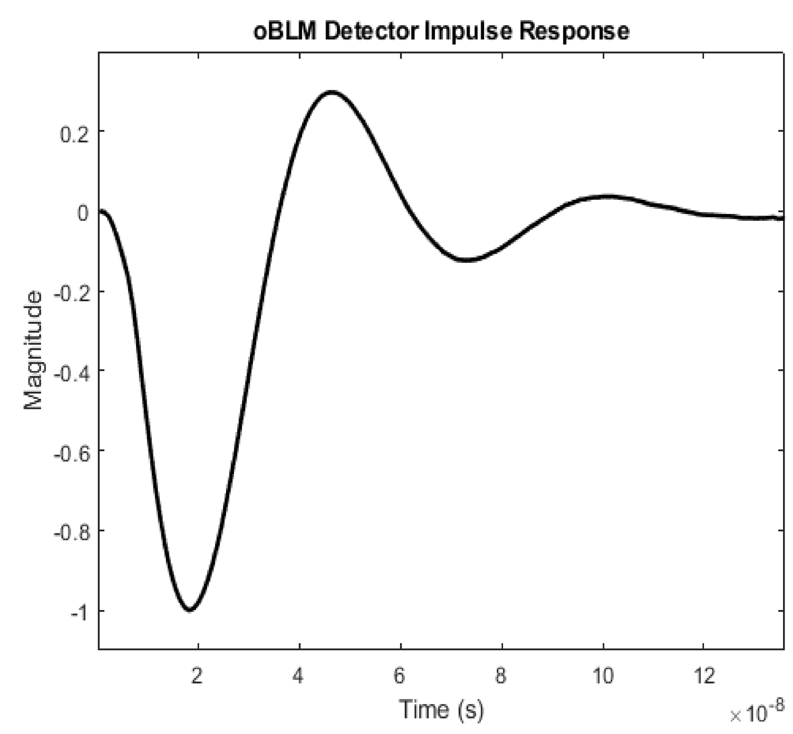






The Signal

The impulse response from each detector of the oBLM is a damped 20MHz oscillation. Multiple beam losses result in a signal that is the sum of impulse responses with different delays and magnitudes. These delays and magnitudes must be determined and processed to gain information about the locations and sizes of beam losses.



The position resolution of a single loss is determined by the accuracy of the arrival time of the response. CLARA (Compact Linear Accelerator For Research Applications) is an electron accelerator with components separated by 0.2m. To resolve to 0.2m a timing resolution of 1ns is required. This is based on the group velocity of light in the quartz fibre which is approximately 2/3 the speed of light in a vacuum.

Commissioning

Four oBLM fibres were placed around the CLARA front end beam line. Commissioning the device involved inserting screens or other devices at known positions along the accelerator and observing the response on one end of each of the four fibres. The delay of the impulse response for each position was recorded and used to provide a calibration value for that fibre. A user interface was then designed that showed the response against a diagram of the machine showing the positions of different components Operators use this to make a judgement about where the beam losses are occurring.

Future Plans

More work is needed to process the signals to reduce both the importance of the operator and the amount of data produced. Waveforms must be analysed by the operator along with the calibrations and a diagram of the machine to estimate the position of the beam loss. Further work is needed to design a method to process these waveforms and instead just give the position and magnitude of the losses. This would be easier to process, understand, save and retrieve.

This is difficult in practice because closely spaced losses are masked by the duration and oscillations of the impulse response. The ability to resolve closely spaced losses is limited by the width of the response. Improvements to the readout electronics and implementation of deconvolution filters are both being investigated to address these challenges.

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